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# THE GENERAL-SCIENCE COURSE IN THE UNIVERSITY HIGH SCHOOL

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## SOME GENERAL PRINCIPLES

When science was first admitted to the American school under the name of natural philosophy it included in a single course the explanation of a very wide range of phenomena belonging to several sciences. In the differentiation which followed upon the expansion of the science curriculum this original generalized course was split up into several distinct sciences. Each of these has been very completely organized within its own field and without reference either to its relations with the other sciences or to the common elements in all science. The consequence is that the science course in the high school lacks continuity. The pupil enters a very specialized work with no previous preparation, and he usually pursues his first work in a particular science without the assistance of the perspective that an elementary knowledge of other sciences would furnish. Each science is taught as if it were in itself a complete system of knowledge unrelated to other science knowledge.

Later years have seen a reaction from this extreme position in the form of a demand for some sort of introductory course which shall precede all existing high-school science courses, and, by the relation of its content and method to the common phenomena of science, in some measure prepare for each of them. The concrete

reply to this demand is the general-science courses which are being tried in so many places in the country.

An earlier attempt was made to meet the need through the work of the elementary school in nature-study or elementary science. That the elementary school has not been able to meet the need completely is sufficiently indicated by the present interest in the general-science movement. That nature-study will meet this demand within a period of time sufficiently short to bring the matter into the present discussion is highly improbable. Each new investigation of the status of nature-study in our elementary schools emphasizes the lack of preparation on the part of the teachers, the limited opportunity for prospective teachers to secure such preparation along with the large amount of other work which their course calls for, and an absurdly small average time actually used in science instruction in the elementary schools of the country. It is perfectly obvious that there must be an extensive change in school methods before science instruction in the elementary schools will be given in sufficient quantity and with such reliability and uniformity that the science program of the high school may be founded upon it. Also, it is not clear to all that such uniformity is desirable in the elementary school. It is evident, then, that the high school must solve its own science problem; it cannot pass the problem down to the grades. It is of course quite possible that the present attempt to increase the efficiency of the seventh and eighth grades, with a view to shortening the time occupied in this part of the school course, may develop the possibility of doing work equivalent to general science in those grades, as a few schools appear to be doing already. This result is more probable if the administration of these two grades is to be transferred to the high school, as is suggested; for the administration of such a course would be easier in connection with the routine of the high school than in the elementary school. This possibility is also sufficiently remote to leave the science problems with the high school for a good while at best.

The University High School early recognized the necessity for an elementary study of the field of all the sciences as a requisite for success in any one of them. It attempted to meet this need in an

experimental way by the organization of short courses in botany, zoölogy, physiography, and physics, to be given in the first and second years to all pupils. The total amount of time consumed in these four courses exceeded that usually given to one unit in science. The usual courses in science were open to election by those who had completed these elementary courses. It was the general opinion that these courses were of decided value, and the record of the pupils in the more advanced courses bears out this opinion. As a first step, this work appears to have been a success, but it could not be the final solution, since the lack of co-ordination between its separate parts was likely to be as great as between any other science courses. As the experiment progressed, it became increasingly evident that the materials used must be combined in a single course, in which the boundary lines between the sciences should be as inconspicuous as possible. In a word, we wished a synthetic course, a general course in science. The present course in general science is the outcome of this feeling.

The work in general science in the University High School is a required course in the first year. It extends through the whole of the first year, and meets five times a week. Two of these meetings are for double periods, making the total time in the classroom seven periods, or about four and a half full hours a week. The course was given in 1910–11 and is being repeated in 1911–12. During the past year there were four sections, averaging over twenty pupils at the close of the year. There are at present also four sections with a slightly smaller number of pupils.

The production of a synthetic course has been kept in mind throughout in the organization of our materials. It is obvious that a course which takes up topics from one science exclusively for a month or a quarter, and follows this during some similar period by a study of material from some other science, is not a general course. The mere fact that four or five short courses in different sciences are pursued consecutively during a single year under the same teacher does not enable such a sequence of studies to qualify as a course in general science. It differs in no essential way from the series of short elementary courses formerly maintained in the University High School, which it was desired to supplant. In the organization

of the new course the boundary lines of the sciences are purposely disregarded. Phenomena which appear likely to seem significant to the pupil, and to be of educative value, are made subjects of study, and the investigation of these phenomena is carried in whatever direction is necessary, regardless of the particular field of science that may be invaded. It sometimes occurs that the treatment of one topic may involve several of the divisions of the field of science, and in other cases the whole matter lies within the domain of a single science. Either contingency is equally a matter of unconcern, provided only that the topic be clear and significant to the pupil, and susceptible of being taught in a scientific manner.

The materials selected for use in constructing this course are particularly those which have some present significance to the pupils. This must not be taken to mean that only those materials are admitted that have an immediate relation to problems of bread and butter. Such significance is not to be neglected, but there are many other ways in which things become significant to adolescent pupils. In fact, a very great many pupils of this age have felt the economic pressure so little that they are not much concerned about the monetary value of their education. Things are significant to them in terms of the life they now lead, rather than in terms of preparation for more remote adult years. The adolescent is usually immensely interested in the new experiences which the world is affording him; he is yet busied in getting an acquaintance with his rapidly expanding world. The implements of his sport, the street car or automobile in which he rides, the source of his food and clothing, health and disease, the ever-changing weather, his daily school tasks, and the varied commercial and industrial activities about him are all meaningful. Compressed air is more important to him in a bicycle tire than in a Boyle's Law apparatus, though he is not afraid of Boyle's Law if it will help him to understand something about the tire.

The work of the school or the problem of the class may be the thing that gives significance in particular cases, so that very often it is not necessary to go outside of the course in science to find plenty of motive. In the work of the classes which are at present taking our course in general science it has been found that interest

was at almost its highest point in the study of the rather abstract matter of the molecular theory. This appears to be due partly to the aid which it gave in the attempt to explain certain facts about the air, and in larger part to the appeal which it made to the imagination. In all cases we have found it possible to secure good work when the pupil felt that he knew what he wanted with the knowledge he was seeking, either in explaining his environment, in solving the problems raised in the classroom, or as a stimulus to his imagination. It is in this light that our selection of significant materials must be considered. In all cases where it was felt necessary to round out the work by the use of materials not likely to be called out by the interest of the pupils we have sought some way of making them significant.

The method of attack upon a new topic may be made to contribute very much to the importance and interest which it assumes in the mind of the pupil. If the matter is one that is familiar in everyday experience, but with some unexplained factors, the beginning is made upon the firm ground of former experience. As quickly as possible the unexplained factors are developed, and the pupil is brought face to face with the problem which in the existing state of his knowledge he cannot solve. The difficulty usually lies in lack of knowledge of associated phenomena. These, then, must be investigated, and from this investigation return is made to the original problem.

This is not at all a new method, but an examination of textbooks in science does not indicate that the authors commonly suppose that such a method will be employed in the classes. In the usual manner of presentation of a subject the topics are so arranged and handled that the first prepares the ground for the second, the second paves the way toward the third, and the third leads on to the next, in a very smooth and easy ascent. But there is nowhere in the first or second topic any indication of that which may be its only reason for being—its application to the main proposition. The carefully graded steps are very pleasing to one who has an outlook over the whole subject, but the pupil does not have this outlook. He finds himself, not upon the highroad, but in an inclosed winding stairway, where he can see nothing excepting that one step leads to another.

With no view of either his surroundings or of the goal toward which he is striving, the way is a weary one. The pupil is continually preparing to meet a future contingency which is never in his sight. That he continues to strive is an indication of great faith in his instructors, where it is not blind fatalism.

This is not the place to discuss the desirability of greater motivation of the work presented to students in college and in the later years of the high school, in which it may be supposed that greater vision and perspective have been developed. Both theory and experience seem to indicate that in the first year of the high school the immediate reason for a particular piece of work needs to be kept above the horizon. In this course, therefore, we frequently introduce topics for the complete consideration of which the pupil is not prepared. As soon as the problem is properly developed the pupil is guided in making a sort of side excursion in quest of the necessary information, later to return to the solution of the original problem. For example, we may take the study of a burning candle. Before investigation of the flame has proceeded far, the teacher will manage to call attention to the presence of water in the flame. The pupils soon convince themselves that the water does not enter the flame as water, and that its presence cannot be explained by any facts with which they are familiar. Usually they are soon convinced that it must have been formed in the flame. Questions regarding the nature of water and the possible method of formation lead to a consideration of water as a chemical compound and some discussion of chemical combination. When, by experiment and reading, some understanding of these things has been secured, it is not difficult to explain the presence of water in the flame. In the course of this study the pupils have been acquiring knowledge of chemical fact and theory, but it has been acquired because they have had a definite present use for it in a concrete situation, and not in the nebulous hope that some future occasion might demonstrate its value.

Our experience has been that the motivation thus furnished is of great importance. It is believed, too, that it is a healthy experience for youth to come face to face with a problem offering real difficulty, and to find that it yields when proper study has been made of all the facts. So are the problems of life solved.

The problem of securing unity in such an apparently diverse mass of materials is one of the most puzzling to arise. The expression "apparently diverse" is used advisedly, for it is in no way evident that the diversity of materials is in reality so great as appears at first sight, nor that it seems so to the pupil. The mature mind, habituated to assorting facts in certain fixed categories, immediately classifies the items in any mass of materials as physical, chemical, biological, and so on, and esteems those items as widely divergent which fall into different groups. The pupil who enters the high school usually not only does not habitually think in terms of physics, chemistry, and biology, but is in fact unable to classify phenomena in these groups with any certainty. It is evident, therefore, that the association of phenomena belonging to a particular science can have no significance to him, excepting as such significance is developed in the study. The associations of phenomena as he finds them in nature are to him much more important than our logical systems. For instance, the successful operation of a motorcycle calls for the practical application of principles in chemistry, the mechanics of solids, pneumatics, electricity, and other branches of science, but to the high-school boy who owns a machine all contingencies which arise are merely parts of the problem of the motorcycle. His notion of the relations of phenomena is valid equally with our own, and a deal more useful to him.

Perhaps it is a fair conclusion that much of the demand for unity in an elementary science course arises from the characteristics of the mature mind and does not find justification in the nature of the child. The reasons for organizing the material around any particular science or series of sciences do not appear to be compelling, unless it be deemed desirable that the first view of the field of science which the child is given shall be a partial view. In that case unity is secured as to particular sciences with discontinuity as regards the pupil's experience. General science seeks to secure unity in a broad view of the field, leaving to later work the delimitation of the fields of the separate sciences and the organization of the fundamental lines of unity in those sciences. Unity there must be, but it is not conceived that it must be of precisely the order that we are used to in more advanced courses.

## ORGANIZATION OF MATERIALS

It is usually assumed that one purpose of the courses in science is to enable the pupil to adjust himself more exactly to his environment. Understanding of environment has been the point of beginning in our arrangement of material. The phenomena may be grouped in many ways. We have chosen to consider the air, the waters, the solid earth, and the living things which inhabit the earth. Taken broadly, these are the divisions commonly recognized by physical geography, and in so far, at least, our organization of material is frankly geographical. These great divisions are taken up in the order mentioned. The air is selected as the one with which to open the work, because it is sufficiently novel and mysterious to attract attention and to raise many questions at the very beginning. In the study of the lands the point of departure is the soil, and this study gains considerable advantage from the preceding study of air and water. The greater complexity of the biological materials has determined the position of this division as the last. It must not be supposed, however, that all biological materials have been postponed to this time. Quite to the contrary, many biological topics are treated at length in the three preceding divisions; but the proportion of biological materials is greater in the last division. This will become more clear as the content of each of the divisions is presented in more detail. In giving this account, the work of last year will be principally in mind, but liberty will be taken to deviate from this on some points which have been revised for presentation to the classes of the present year.

In beginning the work with the air, some questions are raised relating to the reality of the air in the sense that other and familiar substances are real. These questions lead to the study of the most obvious physical characteristics of the air, such as weight, pressure, elasticity, expansion when heated, and humidity. The study of these subjects furnishes plenty of problems leading to a continuation of the subject. The seasonal changes in temperature, usually beginning to be evident during the opening month of school, lead to study of the variations in insolation; the ever-changing atmospheric conditions demand study of the weather; and the elasticity of the air is used to raise questions which lead to a study of the

molecular theory. A candle flame is used to stimulate a study of the chemical nature of the atmosphere, somewhat after the manner of Faraday's famous lectures, and the knowledge secured, first applied to the solution of the problems of the candle itself, is immediately used again in elucidating the relation of green plants to the air and to the food-supply of the world. The study of the composition of the air is completed by some investigation of its dust-content, both organic and inorganic. Bread-cultures by the pupils and agar-cultures by the teachers demonstrate that part of the dust is living, and bring up the whole question of molds and bacteria. There is no intention of requiring any study of these excepting such as may be made by observation of cultures on bread, agar, potato, or milk, but when, as usually occurs, the pupils ask to see the organisms under the compound microscope they are gratified as fully as possible. The house-fly as an agent for the transfer of bacteria cannot be omitted: unfortunately this year a scarcity of material at the proper season hindered as complete laboratory study of the anatomy and life-history of the insect as is desirable. At this point the division on the air is closed.

Starting from the questions regarding the relation of liquids and gases which have developed during the term, a study is made of the freezing and vaporization of water, together with the associated phenomena and their contact with life, from perspiration to "artificial" ice. To this is added an elementary consideration of water-pressures and buoyancy. A very large part of the time allotted to the subject of water is given to study from a geographical point of view. Lake Michigan has been made the center of this line of work. The pupils study concrete data to discover what influence the lake may have had upon the founding of the city and its growth, its present relation to commerce and to climate, to water-supply, and to the disposal of the city's waste. This study is not narrowly restricted, however, but rather it is used to lead out into a broader consideration of the general relations of bodies of water to commerce, climate, and recreation. The question of the water-supply of cities and the disposal of their sewage is given much attention, to the end that the pupil may have at least a budding intelligence about these great civic problems.

The third division is occupied with a study of work and energy. Beginning with the knowledge of the lever which the pupils bring from mathematics, we attempt to build up a notion of work. This notion is then applied to the solution of the problem offered by a set of pulleys or an inclined plane. In successive steps are treated power, heat as a form of energy, transformations, the sun as a source of energy, and the energy-supply of plants and animals.

The fourth division is organized around the most familiar feature of the earth's crust—the soil. In the form of problems regarding the origin, character, and loss of soils, the pupil studies facts that might otherwise be classified as weathering, glaciation, erosion, sedimentation, soil physics and soil chemistry, and the relation of plants to soils. If time permits we shall this year precede soil studies with some consideration of rocks and minerals and a few important mineral products, such as iron and coal.

The last part, including a more systematic survey of man's biological environment, is at present in process of revision with a view to such considerable expansion that it would be quite superfluous to present any analysis at this time. It is believed that the discussion of the other parts has given some notion of the general character of the material, and that the details are not of interest in the present tentative form. Those who are concerned in the construction of the course feel that it is entirely tentative at present, and as such it is presented.

It would not be proper to close this account of the materials of the course without making quite clear the part that others than the writer have had in the constructive work. The inception of the work is due to Dr. O. W.Caldwell, director of the work in natural science in the School of Education; the classes have been taught by the writer and his colleague, Dr. Mary Blount. All three have co-operated in constructing the course.

## RESULTS

The measurement of the results of any course of study in terms of some unit which is so standardized that the results are comparable with other results secured under different conditions is admittedly a difficult thing. A plan for such measurement was outlined at the

beginning of the work and carried through the year, but it has not been found possible to reduce the results to such form that they are comparable with any absolute scale. The perfection of the technique of such investigation is a matter that is engaging the attention of many at the present juncture, but no one has yet been able to point out a valid method of evaluating the results of a series of tests such as were given. There is, therefore, no way known to the writer in which the results of this course may be expressed in a wholly satisfactory manner. There are, however, three methods by which results may be expressed qualitatively if not quantitatively.

Since all courses in science in the University High School excepting general science are elective, it appears possible to secure some measure of the success of this course in arousing interest. It may be assumed that any unusual increase in science-election in the near future, if such be found to occur, should be attributed to the influence of this course. It is intended that such an examination of the data shall be made, but this would be fruitless at the present time, since few of those who were in the general-science course last year have progressed far enough in the required branches to be in a position to exercise their elective privileges in this way.

Possibly more significant than the number of elections is the quality of the work done by those who have had this preparation and later pursue other courses in science. Obviously no conclusion can be drawn in this case until a considerable number of pupils have passed into the higher courses of the school.

The opinion of the teachers of the higher classes has a certain value, even though it be based upon general impressions rather than upon measurement. A number of teachers who are in the best position to see results have expressed themselves as entirely certain that very definite advantage to their work has resulted. This opinion is, of course, founded largely upon the results of the four partial elementary courses previously referred to. It is the feeling of those who have had the most intimate relations to the organization and conduct of the course that it has been a success, though they are possibly more acutely conscious than anyone else of the defects which exist.